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Article 1

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Effect of potato scab treatments on seed vitality: Formaldehyde and corrosive sublimate solutions and formaldehyde gas

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THE EFFECT OF POTATO SCAB TREATMENTS ON SEED VITALITY

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IOWA STATE COLLEGE OF AGRICULTURE AND
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EFFECT OF POTATO SCAB TREATMENTS ON SEED VITALITY

Formaldehyde and Corrosive Sublimate Solutions and Formaldehyde Gas

BY T. J. MANEY.

In three years of experiments at Iowa Agricultural Experiment Station in the use of formaldehyde gas for treating seed potatoes for scab, it was found that the gas greatly reduces the germinating powers of the tubers. The injury not only affects the eyes, preventing germination, but also causes sunken spots about the lenticels. The tubers absorb the gas and retain it and thus are poisoned. In experiments with the usual treatment for potato scab, where the seed is soaked in standard solutions of formaldehyde or corrosive sublimate, it was found that injury results if the tubers are soaked for more than two hours, the injury increasing with the length of treatment. It was also found that in soaking tubers in standard solutions for potato scab they should be placed in the solution whole and not be cut for planting before treatment. Cut tubers when treated for only two hours showed a marked decrease in germination.

These experiments were undertaken in 1910 because, although considerable work had been carried on to test the efficiency of chemical preparations for the prevention of potato scab, very little had been done, especially with formaldehyde gas, to determine the effect which the treatments have on the germinating power and yield of tubers*. For the prevention of scab, formaldehyde and corrosive sublimate solutions have been used most extensively and with best success. Disinfection of seed potatoes with formaldehyde gas was introduced by Morse[1] in 1907. Stewart and Stephens[2] found that formalin solution, when used in the treatment of oats, wheat, and barley, as a prevention for smut, had a marked effect on lowering the germination percentage, even when the solutions were diluted in the proportion of 1 pound of formalin to 60 gallons of water.

THE SOLUTION AND GAS TREATMENTS IN 1910.

In the investigations of 1910, various lots of whole potatoes were treated with formaldehyde and corrosive sublimate solutions and with formaldehyde gas for periods of 2, 6, 12 and 24

*While this bulletin was in preparation for the printer, F. C. Stewart and W. O. Gloyer published "The Injurious Effect of Formaldehyde Gas on Potato Tubers," N. Y. Exp't Sta. Bul's. 369-370, Geneva, N. Y., 1913.

[1]Bul's. 141 and 149, Maine Expt. Sta., 1907.

[2]R. Stewart and J. Stephens, Bul. 108, Utah Expt. Sta., 1910.

hours. As some growers advise cutting the tubers before treatment, one lot of cut tubers was also treated with formaldehyde solution and another with corrosive sublimate. The gas treatments were given in a specially constructed wooden fumigator having a capacity of 24 cubic feet which is hereafter referred to as "the small fumigator."

The standard treatments were used in the solution tests. The formaldehyde solution treatment consists of soaking the tubers for two hours in a solution made by adding one pint of formaldehyde solution to thirty gallons of water. The standard corrosive sublimate treatment consists of soaking the tubers for two hours in a solution of two ounces of corrosive sublimate dissolved in fifteen gallons of water. Both solutions can be used repeatedly. However, formaldehyde evaporates quite rapidly when exposed to the air and, therefore, the vat used in this treatment should be kept covered to prevent loss of strength in the solution. It is not necessary to use this precaution with the corrosive sublimate solution. But corrosive sublimate is a deadly poison and very great care should be taken to keep it out of reach of children and animals.

In the disinfection of tubers with formaldehyde gas, the gas is generated by the use of formaldehyde and potassium permanganate. The standard formula, recommended by Evans[3], is three pints of formaldehyde and twenty-three ounces of potassium permanganate for each 1000 cubic feet of space in the room where treatment is given. Thorough disinfection of seed can be accomplished only in a gas tight compartment called a fumigator. The gas is produced by spreading the potassium permanganate evenly over the bottom of a large pan, or small wash tub, which is called the gas generator, and then adding the formaldehyde. Almost instantly a very rapid chemical reaction takes place and in about five minutes 80% of the available gas is liberated.

All seed treated in 1910 was planted June 6, 1910. Table I gives the date on which the first sprouts appeared above ground.

These results indicate, in a general way, that the rapidity of germination is dependent on the length of time the tubers remain in the solutions or are exposed to the gas.

Observations during the growing season also showed that the germination of the long treatment plots was very light and that the plants lacked vigor.

In the plot planted with potatoes treated with corrosive sublimate solution for six hours, the germination was in no way retarded by the treatment; neither was the subsequent growth which throughout the season was very luxuriant and equalled, if it did not excel, the other plots in the experiment. At digging

[3]Maine State Board of Health Report, 1906.

TABLE I.

SOLUTION AND GAS TREATMENTS, 1910.

TREATMENT	Date Planted	Date Germinated	Remarks
WHOLE TUBERS—			
Check (no treatment) -------	June 6	June 20	A few
Formaldehyde sol. 2 hrs.----	June 6	June 18	5% up
Formaldehyde sol. 6 hrs.----	June 6	June 18	Just started
Formaldehyde sol. 12 hrs.----	June 6	June 27	½% coming very weak
Formaldehyde sol. 24 hrs.----	June 6	June 27	3 or 4 started
Formaldehyde gas 12 hrs.----	June 6	June 23	A few
Formaldehyde gas 24 hrs.----	June 6	June 20	Just starting to come up
Formaldehyde gas 24 hrs.----	June 6	June 27	1% up
Corros. sublimate sol. 2 hrs.	June 6	June 20	20% up
Corros. sublimate sol. 6 hrs.	June 6	June 18	Just starting
Corros. sublimate sol. 12 hrs.	June 6	June 20	A few started
Corros. sublimate sol. 24 hrs.	June 6	June 27	About 1% starting
CUT TUBERS—			
Corros. sublimate sol. 2 hrs	June 6	June 18	A few coming up
Formaldehyde sol. 2 hrs.----	June 6	June 18	A few coming up

time this plot yielded higher than any of the other treated plots, the yield being at the rate of 173.5 bushels per acre. In this case the treatment apparently exerted a stimulating influence on the growth and yield.

The difference between the 6-hour corrosive sublimate treatment and the 12-hour treatment was very marked in regard to growth and percentage of stand. The 12-hour plot fell considerably below the 6-hour yield, producing 124.1 bushels per acre. It is evident that the point of safety to which the treatment with corrosive sublimate solution can be continued lies somewhere between 6 and 12 hours.

The plot planted with potatoes given the 6-hour treatment with formaldehyde solution ranked evenly in general appearance with the 12-hour corrosive sublimate treatment plot. The yield was at the rate of 130.4 bushels per acre. Formaldehyde, undoubtedly, has some sort of a destructive effect on the eye tissues. The tubers treated with the formaldehyde solution were slow in germinating, low in percentage of stand, and less vigorous throughout the growing season.

Only a look at the plot planted with the potatoes treated for 12 hours in the formaldehyde solution was enough to show that something was radically wrong. The tubers were very slow in germinating, the stand was extremely light and the vines were weak. The yield in this case dropped to 43 bushels per acre, whereas the yield of the 12-hour corrosive sublimate plot was 124 bushels per acre.

In the 24-hour treatment with the formaldehyde solution the stand was much poorer than that of the 12-hour plot. The tubers were so slow in germinating that it appeared at first that none would grow. Eventually, the treated tubers made a

TABLE II.

SOLUTION AND GAS TREATMENTS, 1910.

Yield in Bushels Per Acre at Time of Harvesting.

TREATMENT	Marketable bu. per Acre	Culls bu. per Acre	Scab bu. per Acre	Total Yield bu. per Acre
WHOLE TUBERS—				
Check, no treatment	86.73	17.26	4.01	108.00
Corrosive sublimate solution 2 hrs.	133.25	5.87	0	139.09
Corrosive sublimate solution 6 hrs.	173.57	10.17	0	183.74
Corrosive sublimate solution 12 hrs.	124.12	3.35	0	127.47
Corrosive sublimate solution 24 hrs.	32.41	1.06	0	33.47
Formalin solution 2 hrs.	165.35	3.39	0	168.74
Formalin solution 6 hrs.	130.42	9.89	0	140.31
Formalin solution 12 hrs.	43.57	3.89	0	47.46
Formalin solution 24 hrs.	30.40	1.56	0	31.96
Formalin gas 12 hrs.	95.30	4.47	0	99.78
Formalin gas 24 hrs.	57.16	5.71	0	62.87
CUT TUBERS—				
Corrosive sublimate solution 2 hrs.	134.25	7.69	0	141.94
Formalin solution 2 hrs.	89.26	5.82	0	95.08

growth of a few spindling vines which yielded at the rate of about 30 bushels per acre.

The records of yields in the 1910 tests, set forth in table II, bring out most clearly the bad effect which follows when the treatments are continued for too long a time. Six hours seems to be the limit to which the treatment can be continued with any degree of safety. In the case of the corrosive sublimate solution the 6-hour treatment gave a higher yield than the 2-hour. This fact would tend to support the theory that the chemicals up to a certain point exert a stimulating influence on the germination and growth.

The formaldehyde gas does not give satisfactory results, even in the 12-hour treatment. The corrosive sublimate solution for a 2-hour period on cut tubers does not appear to be injurious. However, the 2-hour treatment with formaldehyde on cut tubers does have a bad effect, as is shown by the low yield, which is only 89.2 bushels per acre.

The scab on the check plot was not very bad in 1910; only 4.01 bushels out of 108 bushels were infected. In all cases the treatments acted as a preventative against the disease.

SOLUTION AND GAS TREATMENTS, 1911.

In order to verify the rather unusual results obtained the previous year, the experiments of 1910 were duplicated in the laboratory in the spring of 1911. In addition, more work was carried on with cut tubers. For each of the tests, ten sound tubers with vigorous looking eyes were selected and planted whole. In the treatments where the cut tubers were used a piece weighing about 2 ounces and having but one good eye was

cut from near the middle portion of each tuber. Ten such pieces were used in each test.

The formaldehyde used in 1910 was the ordinary bulk formaldehyde, which was purchased at one of the city drug stores. It was thought that the unusual results of 1910 might have been caused by the use of this grade of formaldehyde, so in the tests of 1911 both the bulk material and the regular branded "Formalin," 40% formaldehyde gas solution, were used. In the tables reference will be made to the solutions as bulk formaldehyde and commercial "Formalin" respectively.

The different lots of treated tubers were planted May 3 and were dug up June 6 and photographed. The percentage of germination and the amount and vigor of growth are shown in plates I to XII.

SUMMARY OF EXPERIMENTS ILLUSTRATED BY PLATES I-XII.

In reality, very little explanation is necessary for the accompanying plates; they speak clearly for themselves. It is quite evident that all the solutions have a detrimental effect on the vigor and growth of the tubers. Especially is this true if the treatment is continued longer than 6 hours. The gas treatment for 24 hours, as is often recommended, is evidently not a safe method. It is a question whether it is effective against the scab if it is used in weaker strengths or for shorter periods. One thing is brought out quite clearly, and that is the fact that under no circumstances should cut tubers be treated with any of the disinfectants, as the cut tissue seems to be very susceptible to the injurious action of the chemicals.

In the experiment with formaldehyde gas at the Maine Experiment station[4] the disinfection was given in a room large enough to treat 75 bbls. of potatoes at one time in the basement of a barn. The ceiling and walls were made as tight as possible.

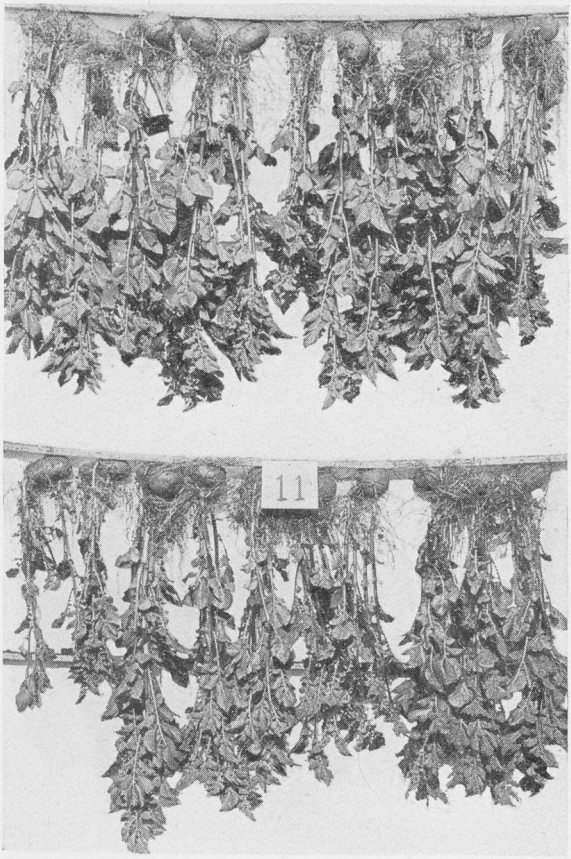
Formaldehyde has such great penetrating powers that it is questionable if such a room could be made gas tight in the manner described. The gas will escape through the smallest opening. Sometimes in a room which is not properly sealed the odor of gas will be unbearable and still the greater part of the gas will have escaped. Thus we cannot judge the amount of gas present by the odor alone. It is absolutely necessary to make the compartment gas tight.

The fact that in our experiments we had used a small fumigator and quantities of material proportionate to the regular formula, while the treatment at the Maine Experiment station was carried on in a fumigator with a capacity of nearly 1350 cubic feet, led us to inquire whether the difference in size had something to do with the amount of injury produced.

[4]Bul's. 141 and 149, Maine Expt., 1907.

Plate I. Vines grown from medium sized, sound, untreated tubers.

As far as vigor and growth are concerned this lot was by far the best of all the plots. The vines were so strong and the foliage so luxuriant that one could easily pick out the check plot from among the other treatments. In the upper lot of 10 tubers shown in the photograph the aggregate growth in height was 281 inches or an average of over 28 inches per plant. In the lower lot of tubers the growth amounted to 236 inches; average 23.6 inches per plant.



2 hours. 100% Germination.

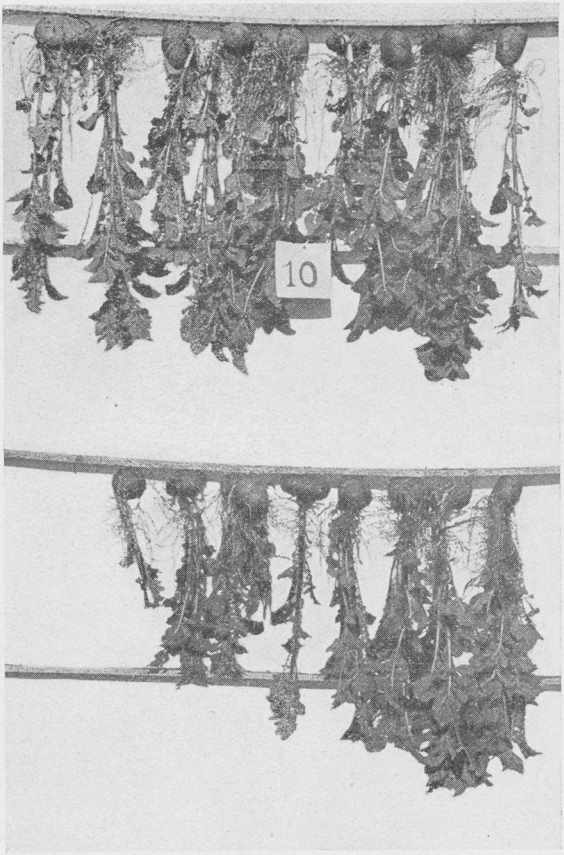
6 hours. 100% Germination.

Plate II. Tubers treated 2 and 6 hours with bulk formaldehyde solution.

Tubers treated two hours: Germination, perfect; vigor and growth compare very favorably with the checks; total growth in height, 239 inches; average 23.9 inches per plant.

Tubers treated 6 hours: Germination, 100 per cent; vines fairly vigorous but showed indications of being somewhat weaker than the two hour treatment; total growth in height, 208 inches; average, 20.8 inches per plant.

12 hours.
90% Germination.

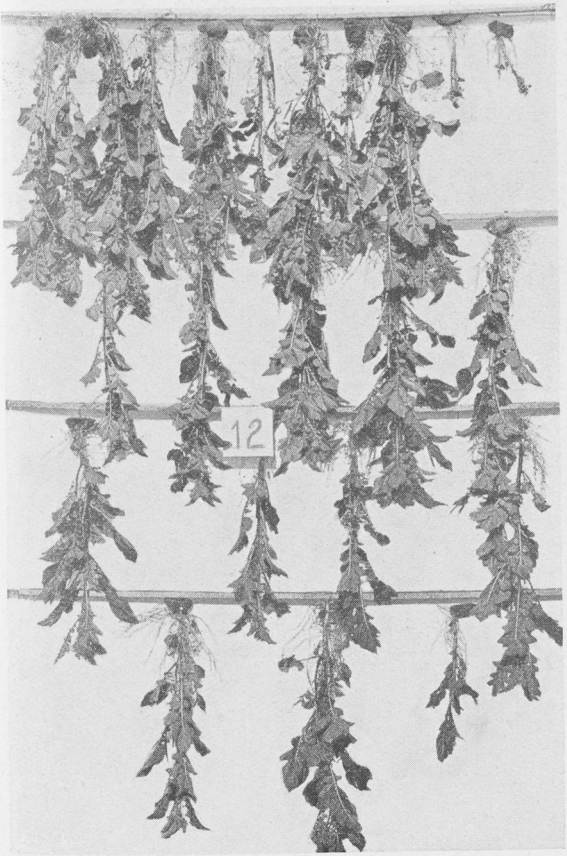


24 hours.
80% Germination.

Plate III. Tubers treated 12 and 24 hours with bulk formaldehyde solution.

Tubers treated twelve hours: Germination, 90 per cent; plants not vigorous, but just a trifle weak; total height, 176 inches; average 17.6 inches per plant.

Tubers treated twenty-four hours: Vines visibly affected; germination, 80 per cent; total growth in height, 130 inches, or more than 100 inches less than 2 hour treatment; average 13 inches per plant.



2 hours.
100% Germination.

6 hours.
50% Germination.

12 hours.
40% Germination.

24 hours.
30 % Germination.

Plate IV. Cut tubers treated 2, 6, 12 and 24 hours with bulk formaldehyde solution.

The tubers were all cut to one good strong middle eye. In all cases the vigor of the plants was affected by the solution.

Tubers treated two hours: Germination, 100 per cent; growth of the vines not very vigorous; total growth in height, 102 inches; average 10.2 inches per plant.

Cut tubers treated 12 hours: Germination, 40 per cent; growth in height, 76½ inches; average 7.6 inches per plant.

Cut tubers treated twenty-four hours: Germination, 30 per cent; total growth in height, 51 inches; average 5.1 inches per plant.

2 hours.
100% Germination.

6 hours.
100% Germination.

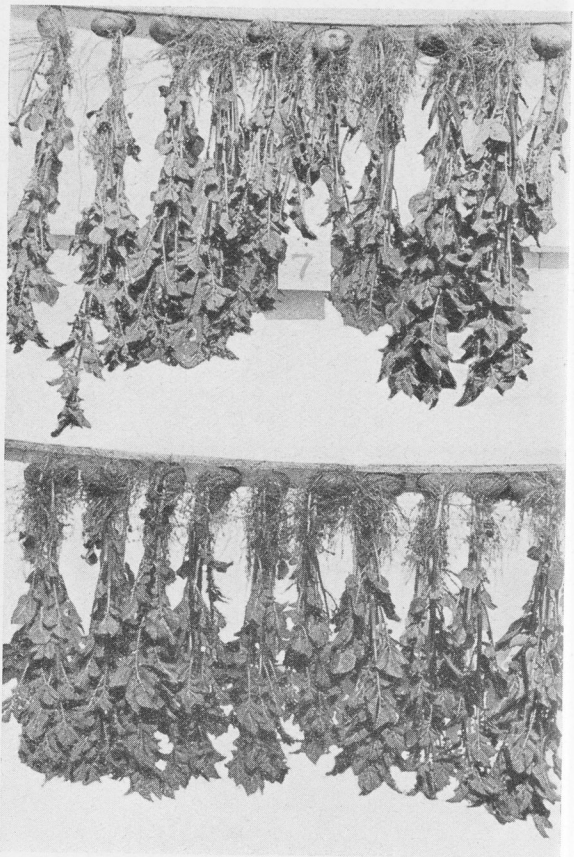
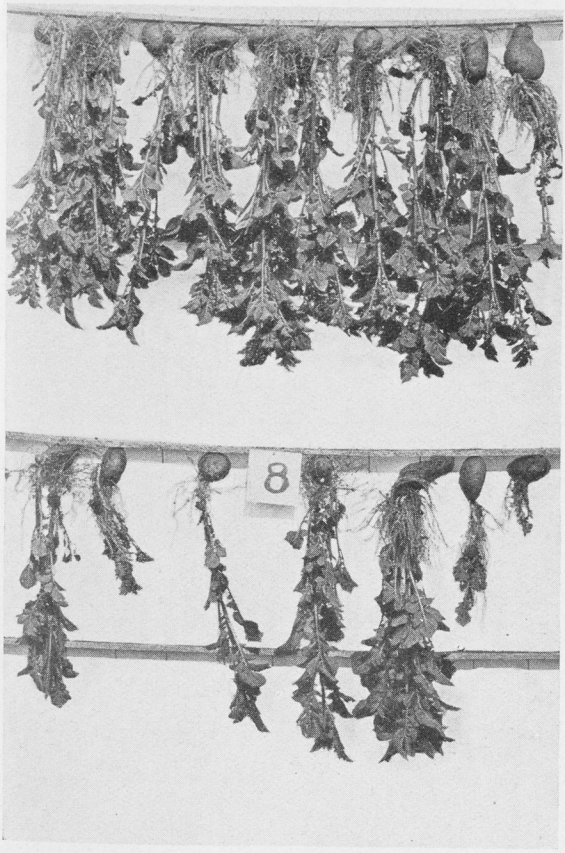


Plate V. Tubers treated with formalin solution.

The treatments for 2 and 6 hours were identical in respect to the percentage of germination and to the amount and vigor of growth. The germination in each case was 100 per cent and the total amount of growth was 218½ inches; average, 21.8 inches per plant.



12 hours.
100% Germination.

24 hours.
70% Germination.

Plate VI. Tubers treated 12 and 24 hours with formalin solution.

Tubers treated 12 hours: Germination, 100 per cent; general appearance, same as in the 2 and 6 hour treatments; total growth in height, 212½ inches; average, 21.2 inches per plant.

Tubers treated 24 hours: Very badly injured by the "formalin" solution; germination, 70 per cent; growth of vines either stunted or spindling; total growth in height, 99½ inches; average 9.9 inches per plant.

2 hours.
100% Germination.

6 hours.
80% Germination.

12 hours
40% Germination.

24 hours.
No Germination.

Plate VII. Cut tubers treated for 2, 6, 12 and 24 hours in the formalin solution.

The tubers were all cut to one strong middle eye. In every instance the growth was more or less spindling.

Cut tubers treated 2 hours: Germination, perfect; total growth in height, 167 inches; average, 16.7 inches per plant.

Cut tubers treated 6 hours: Germination, 80 per cent; total growth in height, 124½ inches; average, 12.4 inches per plant.

Cut tubers treated 12 hours: Germination, 40 per cent; total growth in height, 63 inches; average 6.3 inches per plant.

Cut tubers treated 24 hours: No germination.

The four treatments shown in this plate demonstrate that it is not advisable to treat cut tubers even for a period of 2 hours.

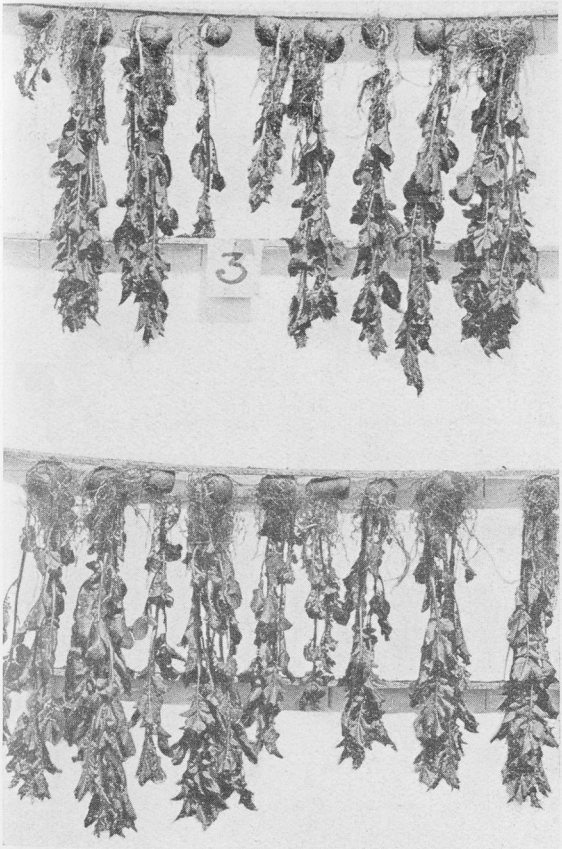


Plate VIII. Tubers treated in small fumigator with gas from bulk formaldehyde and potassium permanganate.

Tubers treated two hours: Germination, 90 per cent; vigor of some visibly affected; some vines stunted, others spindling; total growth in height, 170 inches; average, 17 inches per plant.

Tubers treated six hours: Greater and more vigorous growth than two hour treatment; growth quite uniform, aggregating 187½ inches in height; average, 18.7 inches per plant.

Tubers treated twelve hours: Germination, 100 per cent; vines lacked somewhat in vigor.

Tubers treated twenty-four hours: Germination, 50 per cent; vines lacked vigor.

The wooden fumigator used had a capacity of 24 cubic feet. About 10 pounds of seed was exposed at each treatment, making less than ½ pound to each cubic foot. Stewart and Gloyer[8] state: "By the property of absorption the potatoes seize and hold the formaldehyde gas upon their surface. If there are but few potatoes they absorb so much gas that the tissue is injured; but when the gas is distributed over a large quantity of potatoes it does not gather at any point in sufficient quantity to cause injury."

[8]Bul's. 369 and 370, N. Y. Expt. Sta., Geneva, 1913.

2 hours.
70% Germination.

6 hours.
50% Germination.

12 hours.
30% Germination.

24 hours.
50% Germination.

Plate IX. Cut tubers treated in small fumigator with gas from commercial "formalin."

Before the treatment the tubers were cut to one strong middle eye. In all the treatments the injurious effect of the gas is apparent.

Cut tubers treated 2 hours: Germination, 70 per cent; total growth in height, 140 inches; average, 14 inches per plant.

Cut tubers treated 6 hours: Germination, 50 per cent; total growth in height, 93 inches; average, 9.3 inches per plant.

Cut tubers treated 12 hours: Germination, 30 per cent; total growth in height, 55½ inches; average, 5.5 inches per plant.

Cut tubers treated 24 hours: Germination, 50 per cent; total growth in height, 78½ inches; average, 7.8 inches per plant.

Here, as with the cut tubers treated with the "formalin" solution, injury is decidedly apparent in all treatments.

2 hours.
100% Germination.

6 hours.
100% Germination.

Plate X. Tubers treated with corrosive sublimate solution 2 and 6 hours.

Tubers treated 2 hours: Germination, 100 per cent; two vines stunted, but remainder very vigorous; total growth in height, 211½ inches; average, 21.1 inches per plant.

Tubers treated 6 hours: Germination, 100 per cent; growth uniform and quite vigorous; total growth in height, 211 inches; average, 21.1 inches per plant.

12 hours.
100% Germination.

24 hours.
90% Germination.

Plate XI. Tubers treated for 12 and 24 hours with the corrosive limate solution.

Tubers treated 12 hours: Results better than with the two or six hour treatment; germination, 100 per cent; growth uniform; total growth in height, 213½ inches; average, 21.3 inches per plant.

Tubers treated 24 hours: Germination, 90 per cent; vines stunted rather than spindling as in the formaldehyde treatment; total growth in height, 105 inches; average, 10.5 inches per plant.

2 hours.
100% Germination.

6 hours.
30% Germination.

12 hours.
20% Germination.

24 hours.
20% Germination.

Plate XII. Tubers cut to one eye and treated with corrosive sublimate solution.

The bad effects of the solution on the cut tissue is very noticeable in all treatments.

Cut tubers treated 2 hours: Germination, 100 per cent; all vines lack the vigor of whole tubers treated for same time; total growth in height, 165¾ inches; average, 16.5 inches per plant.

Cut tubers treated 6 hours: Germination, 30 per cent; total growth in height, 47 inches; average, 4 7 inches per plant.

Cut tubers treated 12 hours: Germination, 20 per cent; total growth in height, 21 inches; average, 2.1 inches per plant.

Cut tubers treated 24 hours: Germination, 20 per cent; total growth in height, 18 inches; average, 1.8 inches per plant.

PLATE XIII.—Tubers showing injury from formaldehyde gas. Note sunken tissues about the eyes.

GAS TREATMENTS IN 1912.

In 1912, in addition to carrying on tests similar to those of the year previous, the other object of the work was to note the difference in the amount of injury produced by treatments of tubers with gas in large and small fumigators.

The small fumigator which was used in 1910 and 1911 was again brought into service. For the large fumigator a cconcrete apple storage cellar, having a capacity of 2016 cubic feet, was used. The room had a concrete floor, walls, and ceiling, which were white washed. By sealing the ventilating apertures and the cracks about the door with a plaster made from clay, the chamber was made gas tight.

In all the treatments, except those treatments with gas in the storage cellar, 20 to 25 tubers were used. In the gas treatments of the seed several lots were placed in small baskets and set in various parts of the room. Previous experiments in Maine showed that potatoes near the gas generator were badly injured, so, in the disinfection the tubers in 1912, some were placed near the gas generator, some as far away as possible, about 10 feet, some near the ceiling, some on the floor, and in several other parts of the room.

Sound tubers of medium size were selected. The sprouts had started somewhat and so were rubbed off. The potatoes were then allowed to stand a week to harden up in the eyes before treatment took place. On one lot in the 12-hour treatment the sprouts were not removed. In table III it will be observed that this lot stood third in germination percentage, and in yield ranked higher than the check. It is claimed that seed which never has had the first sprouts removed gives a better yield than seed which has been sprouted. The evidence here seems to support this claim.

After the treatments had been given, the potatoes which had been exposed to the gas in each fumigator were examined. The lots which had been treated for 12 hours and longer plainly showed the injurious effects of the gas. The eyes on many were brown and shriveled and the skin was dotted with small sunken areas of hardened tissue, as is shown in plate XIII.

The tubers shown in this cut were treated for 24 hours with formaldehyde gas of the prescribed strength. The disinfection was given in the large fumigator. The whole surface of the tubers was pitted and the area around the eyes was sunken to a depth of ⅛ to ¼ of an inch. The eye tissue appeared to be severely burned. The tubers which were photographed stood at least 8 feet from the gas generator. The injury from the gas becomes evident in a very short time after treatment, whereas the formaldehyde and corrosive sublimate solutions causes no noticeable injury.

In this work about three bushels were treated at a time in the large fumigator. Stewart and Gloyer[5] state that the lenticel injury, the destruction of the cells around the natural "breathing pores," is caused by the small quantity of tubers per cubic foot of space in the fumigator. The use of the large fumigator, the very small amount of tubers used here, and the injury received, bears out this statement.

In some of the experiments of Stewart and Gloyer stones were substituted for tubers in the gas treatment. In order to note what effect the increased absorbing surface would exert in preventing injury to a test lot of tubers treated at the same time, 1845 stones about the size of tubers were treated along with 20 pounds of tubers. In the first of their experiments, where the tubers were just commencing to sprout, not a trace of injury occurred. In the second experiment the sprouts were about ¼ of an inch long; the only injury was a slight browning of the tips and bases of some of the larger sprouts. In the third experiment the sprouts were ¼ to ½ inch long. Several of the larger sprouts were browned a little at the base and a few were killed, but the eyes sprouted and the germination appeared normal. There was no lenticel injury.

In a number of their experiments, where 12 to 40 tubers were treated in the same fumigator, but without the stones, the eye injury and lenticel spotting usually was severe.

In the Iowa experiment the fumigation was given in a storage cellar which had walls, floor and ceiling of rough cement covered with a coat of whitewash. It is a question whether or not this area of surface would not have a great tendency to absorb the gas as did the stones.

SOLUTION AND GAS TREATMENTS, 1912.

The seed which was treated in the large fumigator was planted on July the first. Frequent examinations showed that the seed treated longest was much slower in germinating than that which had been treated for shorter periods. In tables III and IV the number of tubers planted, the germinating percentage and the amount of potatoes harvested are indicated.

As a whole, the lines of treatment for 1912 tend to support the data obtained in 1910 and 1911.

In the small fumigator the average germination for the 12-hour test was 72 per cent; in the large one, for the same treatment, it was 68.2 per cent. The 24-hour test in the small fumigator showed 56 per cent of germination, while the same test in the large one gave 57.6 per cent.

[5]Buls. 369 and 370, N. Y. Expt. Sta., Geneva, 1914.

TABLE III. SOLUTION TREATMENTS, 1912.

TREATMENT	No. Planted	Per cent Germinated	Lbs. Harvested
WHOLE TUBERS—			
Check, no treatment	50	98.0	30.00
Formaldehyde solution 2 hrs.	25	100.0	15.00
Formaldehyde solution 6 hrs.	25	93.0	16.00
Formaldehyde solution 12 hrs.	25	60.0	9.75
Formaldehyde solution 24 hrs.	25	12.0	1.12
Corrosive sublimate solution 2 hrs.	20	100.0	13.00
Corrosive sublimate solution 8 hrs.	20	100.0	15.00
Corrosive sublimate solution 12 hrs.	20	100.0	10.75
Corrosive sublimate solution 24 hrs.	20	35.0	5.75
CUT TUBERS—			
Formaldehyde solution 2 hrs.	20	75.0	8.12
Formaldehyde solution 6 hrs.	20	30.0	3.75
Formaldehyde solution 12 hrs.	15	6.5	.50
Formaldehyde solution 24 hrs.	12	0.0	0.00
Corrosive sublimate solution 2 hrs.	20	95.0	10.00
Corrosive sublimate solution 6 hrs.	20	65.0	6.75
Corrosive sublimate solution 12 hrs.	20	80.0	7.12
Corrosive sublimate solution 24 hrs.	20	15.0	.37

TABLE IV. GAS TREATMENTS, 1912.

TREATMENT	No. Tubers Planted	Per cent Germinated	Lbs. Harvested
Check	50	98.0	30.0
24 Hrs. Gas Treatment Large Fumigator.			
7′ from generator 3′ above floor	25	80.0	12.0
12′ from generator 3′ above floor	25	80.0	11.0
7′ from generator 4′ above floor	25	80.0	9.75
6′ from generator 4′ above floor	20	75.0	10.5
2′ from generator 2′ above floor	25	64.0	2.5
10′ from generator near ceiling	24	25.0	3.0
12 Hrs. Treatment Small Fumigator.			
8′ from generator 4′ above floor	25	96.0	15.0
12′ from generator 3′ above floor	25	96.0	15.5
10′ from generator 3′ above floor (seed sprouted)	25	88.0	19.0
7′ from generator 4′ above floor	25	76.0	14.0
2′ from generator 2′ above floor	25	56.0	9.5
6′ from generator near ceiling	20	45.0	6.0
10′ from generator near ceiling	25	60.0	10.5
36 Hrs. Gas Treatment Large Fumigator.			
12′ from generator 3′ above floor	24	38.0	5.5
Gas Treatment Small Fumigator.			
2 hrs.	25	92.0	16.0
6 hrs.	25	88.0	14.75
12 hrs.	25	72.0	13.25
24 hrs.	25	56.0	12.75

The location of the tubers in respect to the gas generator has a marked effect on the germination, as is shown by the high percentage of injury to the seed placed near the generating gas. The greatest amount of injury was evident on the seed that was near the ceiling.

According to Mayer and Wolpert[6], the concentration of formaldehyde gas is greater near the ceiling than at the floor. Stewart and Gloyer[7] found that in experiment 23 of their investigation the tubers on the floor were quite as seriously injured as those near the ceiling. Results of the Iowa experiment indicate greater concentration of the gas near the ceiling as in the work of Mayer and Wolpert.

In connection with the formaldehyde solution treatment an interesting fact was noted. Some tubers for general planting were treated in a barrel. After two hours the formaldehyde solution was drawn off, but the tubers were left in the barrel in a wet condition for about a day. Scattered through the plots in which this seed was planted were many vacant spaces. This lot of seed evidently had been injured by the formaldehyde solution which remained on the surface of the tubers while they remained in the barrel in a damp condition. This emphasizes the necessity of spreading the tubers out to dry immediately on removing them from the solution.

In other experiments under observation by the writer, but not reported on, it was noted that tubers treated in December, while the eyes were in a very dormant condition, were not injured to any extent by the solution or gas treatments. In all the experiments reported in this bulletin the aim was to select tubers which would be comparable to the tubers selected by the average farmer.

SUMMARY.

As a result of the investigations for 1910, 1911, and 1912, the following conclusions may be drawn:

1. Whole tubers may be treated for scab by soaking in formaldehyde solution, 1 pint formaldehyde to 30 gallons of water, or corrosive sublimate solution, 2 ounces to 16 gallons water, for periods ranging from 2 to 6 hours, without much noticeable injury to the germinating powers of the tubers. If the tubers are left in the solution for longer periods, or are not spread out to dry immediately, the injury is almost certain to be severe. As a matter of safety in handling, the formaldehyde solution treatment is recommended.

2. Seed tubers should never be cut before treating for the prevention of scab.

3. Formaldehyde gas treatment, while it is efficient in preventing scab infection, cannot be used with safety in the proportions now recommended, because of its injurious effect on germinating power of the tubers.

[6]Hyg. Rundschau (1901), XI, p. 157.
[7]Buls. 369 and 370, N. Y. Expt. Sta., Geneva, 1914.